CLIMATE AND ENERGY POLICY LABORATORY
SCHOOL OF PUBLIC POLICY

Georgia Tech Center for Distributed Energy

Introduction: Vulnerability of U.S. Energy Infrastructure to Coastal Flooding

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Sea Level Rise (SLR): The Global Context

Melting of the ice sheets in Greenland and Antarctica could result in sea-level changes that could severely affect the densely populated coastal regions on Earth.

- Greenland-6 to 7 m of potential sea level
- West Antarctica-6 to 8 m of potential sea level
- East Antarctic Ice Sheet-65 to 67 m of potential sea level

Sources: Williams and Hall (1993), Kim Cobb (2017), and https://pubs.usgs.gov/fs/2005/3055/

"Will We Survive Climate Change?"

A sudden 80 m SLR would be catastrophic:

- All but a few major cities would be inundated
- Over 136 port cities with over a million people would be inundated by 64 m of SLR.

But global warming does not provide enough heat to melt all of the ice sheets suddenly.

The latest Intergovernmental Panel on Climate Change report gives a likely rise in 2100 from 0.28–0.98 m.

There is time for mitigation and adaptation.

Source Mendelsohn: https://cepl.gatech.edu/sites/default/files/attachments/robert-mendelsohn-gatech-seminar-2018-11-29.pdf; Church and Clark, 2013

#drownyourtown

Sources: http://www.southernfriedscience.com/science-in-the-fleet-what-would-youre-hometown-look-like-with-80-meters-sea-level-rise/#more-15649

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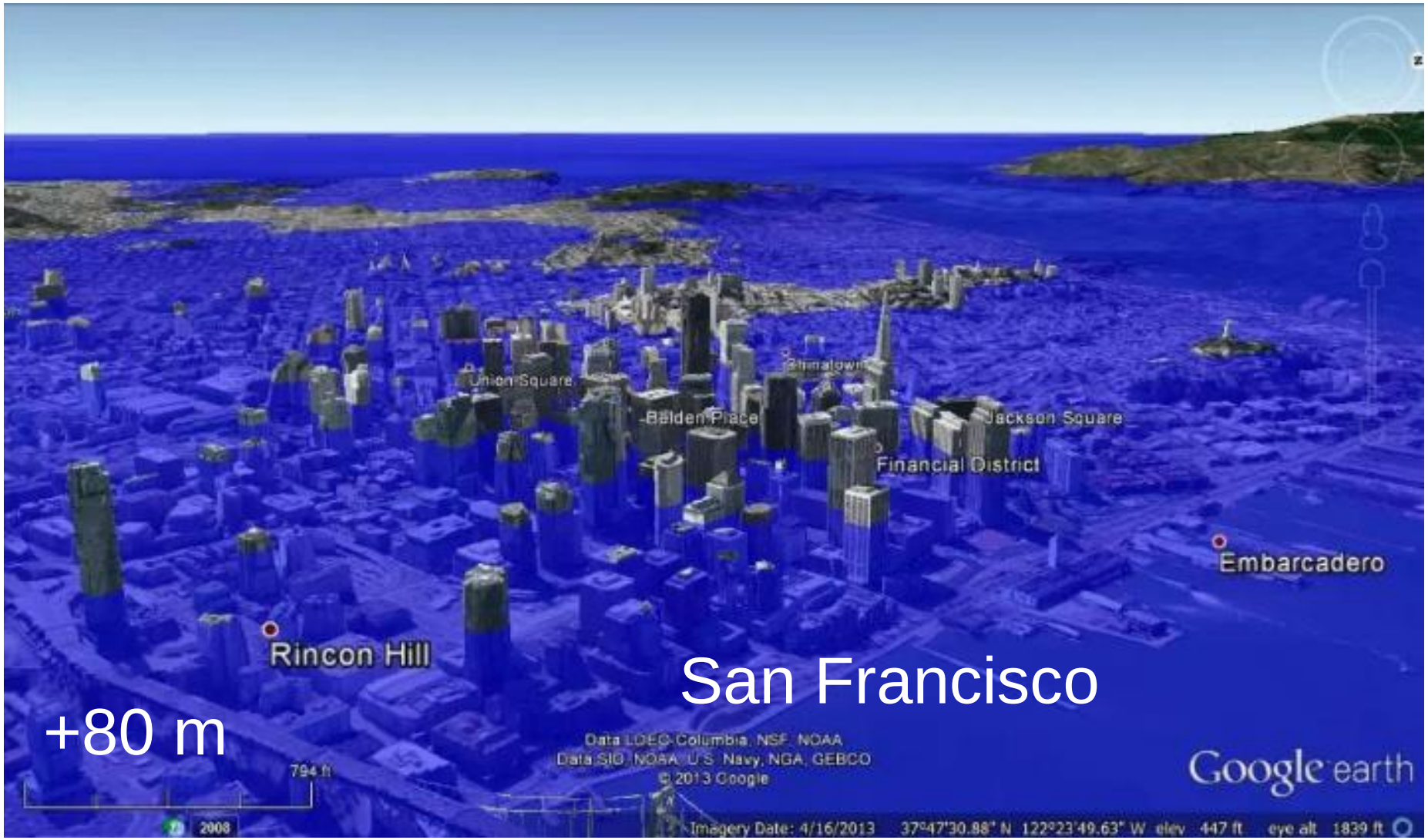


Sources: http://www.southernfriedscience.com/science-in-the-fleet-what-would-youre-hometown-look-like-with-80-meters-sea-level-rise/#more-15649

Protect and Retreat

Need to keep the long-term game plan in mind:

- Protect: construct physical barriers e.g., build walls around urban areas, dam harbors (the Mediterranean Sea at Gibraltar and San Francisco Bay at the Golden Gate Bridge)
- Retreat: relocate inland

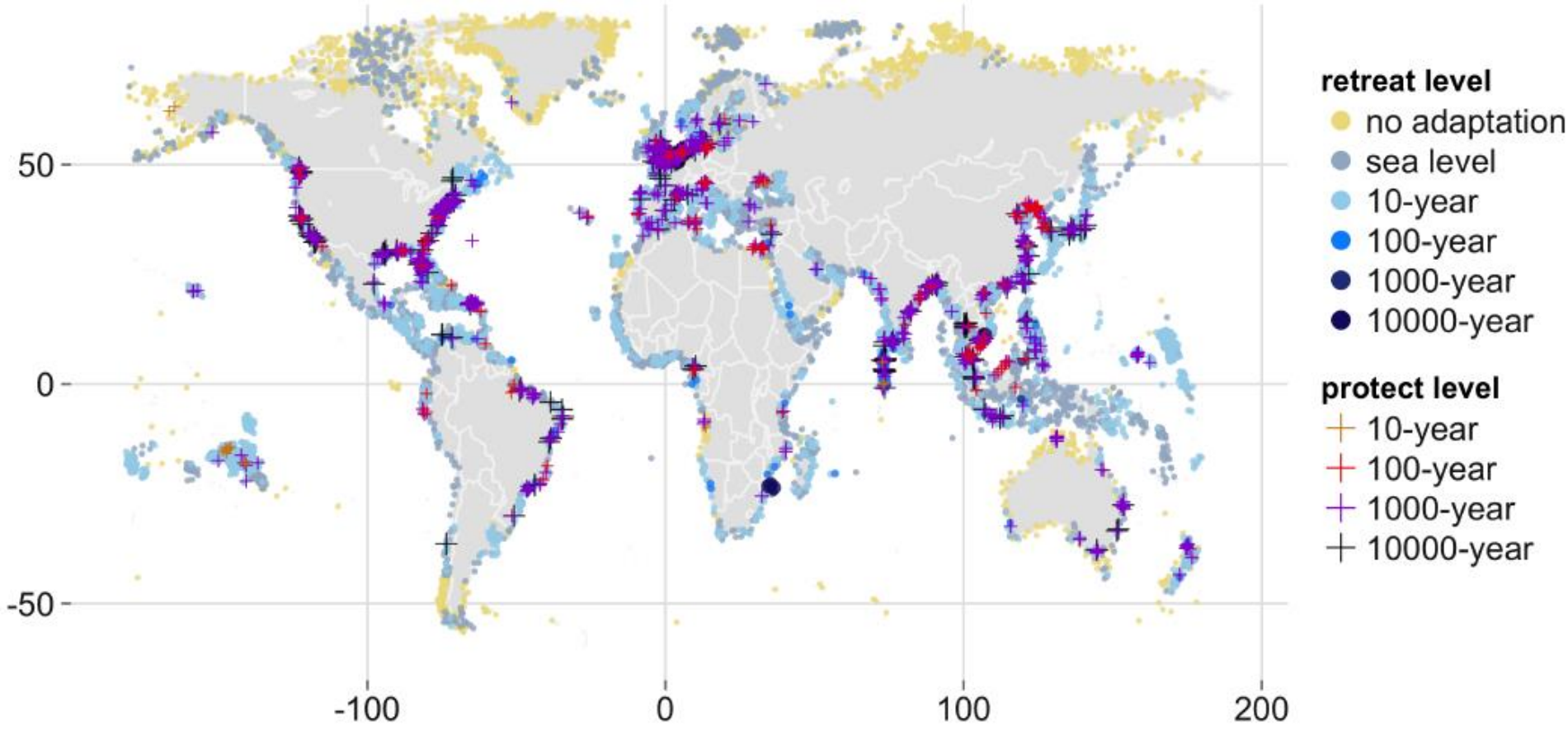
In CIAM (by Delavane Diaz, 2014):

For each coastal segment, the local planner evaluates the adaptation strategies for the cost minimization problem

$$\min_{s} \sum_{t \in \Delta t} \left(\frac{1}{(1+r)^t} \left(\text{ProtectionCost}_{s,t} + \text{RetreatCost}_{s,t} \right. \right.$$

$$\left. \left. + \text{InundationCost}_{s,t} + \text{WetlandCost}_{s,t} + \mathbb{E}\left[\text{FloodCost}_{s,t}\right] \right) \right) \qquad (1)$$

Protect or Retreat



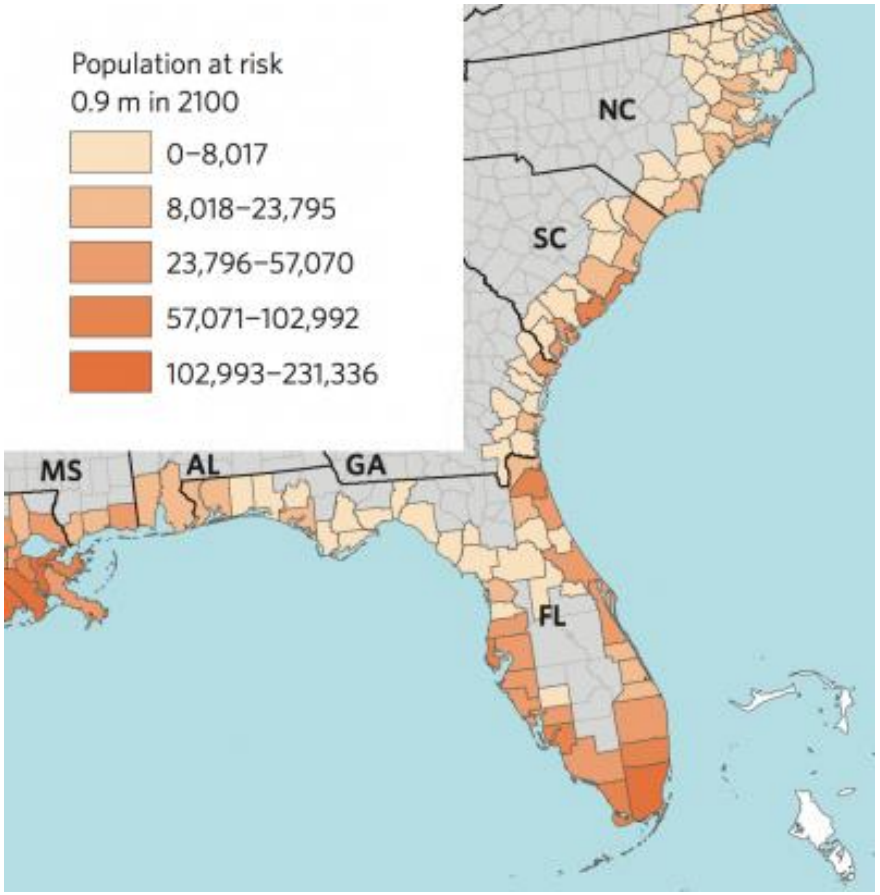
At the local level, Diaz finds that “retreat” is often a more cost-effective strategy than “protect.”

Source: Delavane Diaz, 2014

U.S. Population at Risk in 2100

U.S. population at risk of inundation in 2100:
– 4.2 million with 0.9 m SLR
–13.1 million with 1.8 m SLR

"the absence of protective measures could lead to US population movements of a magnitude similar to the twentieth century Great Migration of southern African-Americans"



http://www.nature.com/nclimate/journal/v6/n7/full/nclimate2961.html

Robert Kopp et al. (2016)

Energy Facilities at Risk

In the lower 48 U.S. states, 287 coastal energy facilities are within 4 feet of ordinary high-tide.

Energy infrastructure includes:

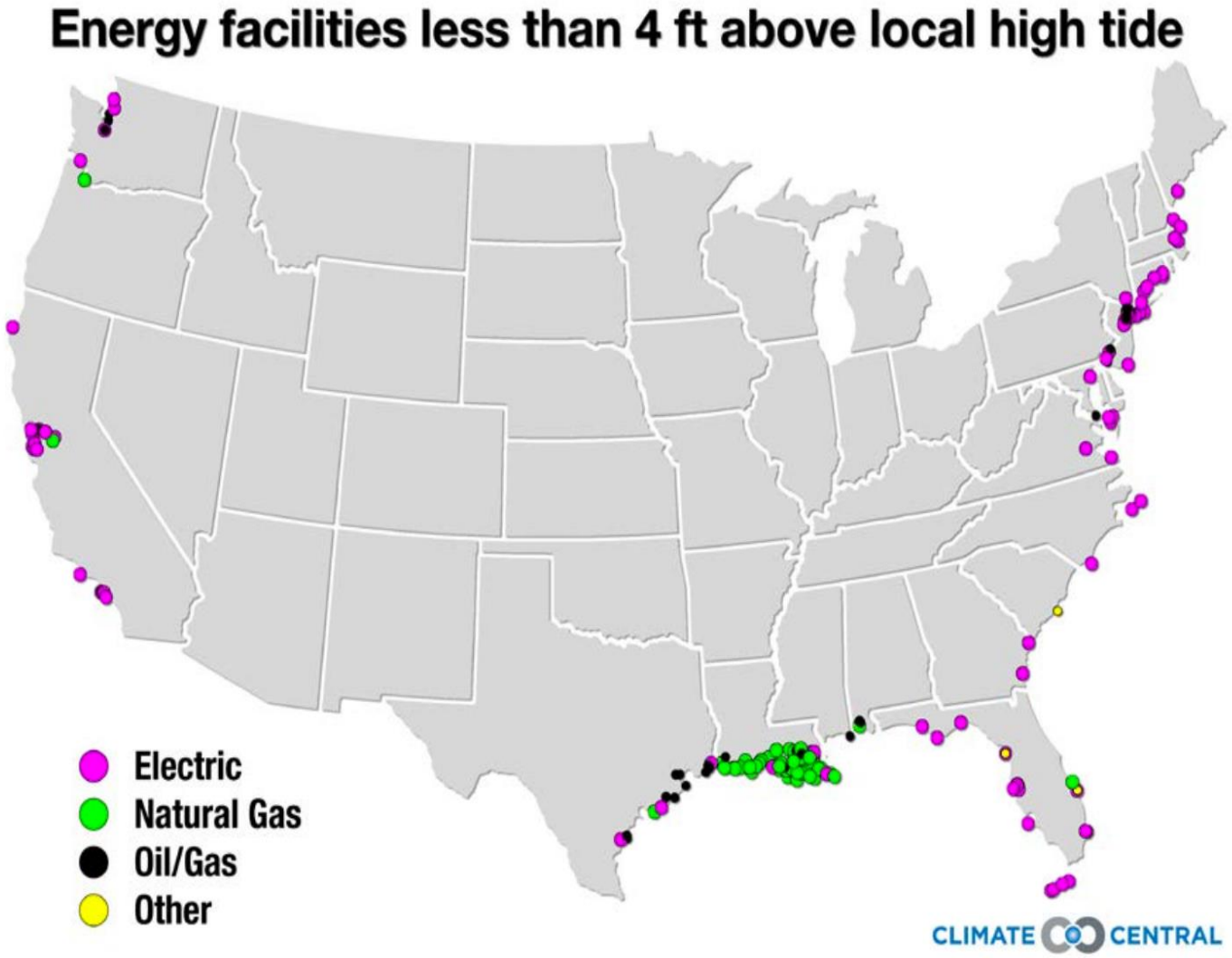
- natural gas infrastructure,
- electric power plants,
- oil and gas refineries

(esp. LA, FL, CA, NY, TX & NJ).

On-shore coastal energy infrastructure also includes the electrical grid, pipelines, and port facilities.

Source: Strauss and Ziemlinski, 2012

Coastal Energy Facilities at Risk



Source: Strauss and Ziemlinski, 2012

Energy Facilities at Risk

From the 2005 hurricanes Rita and Katrina, the oil industry learned that closures of gas-processing plants were caused not only by flooding, but also by:

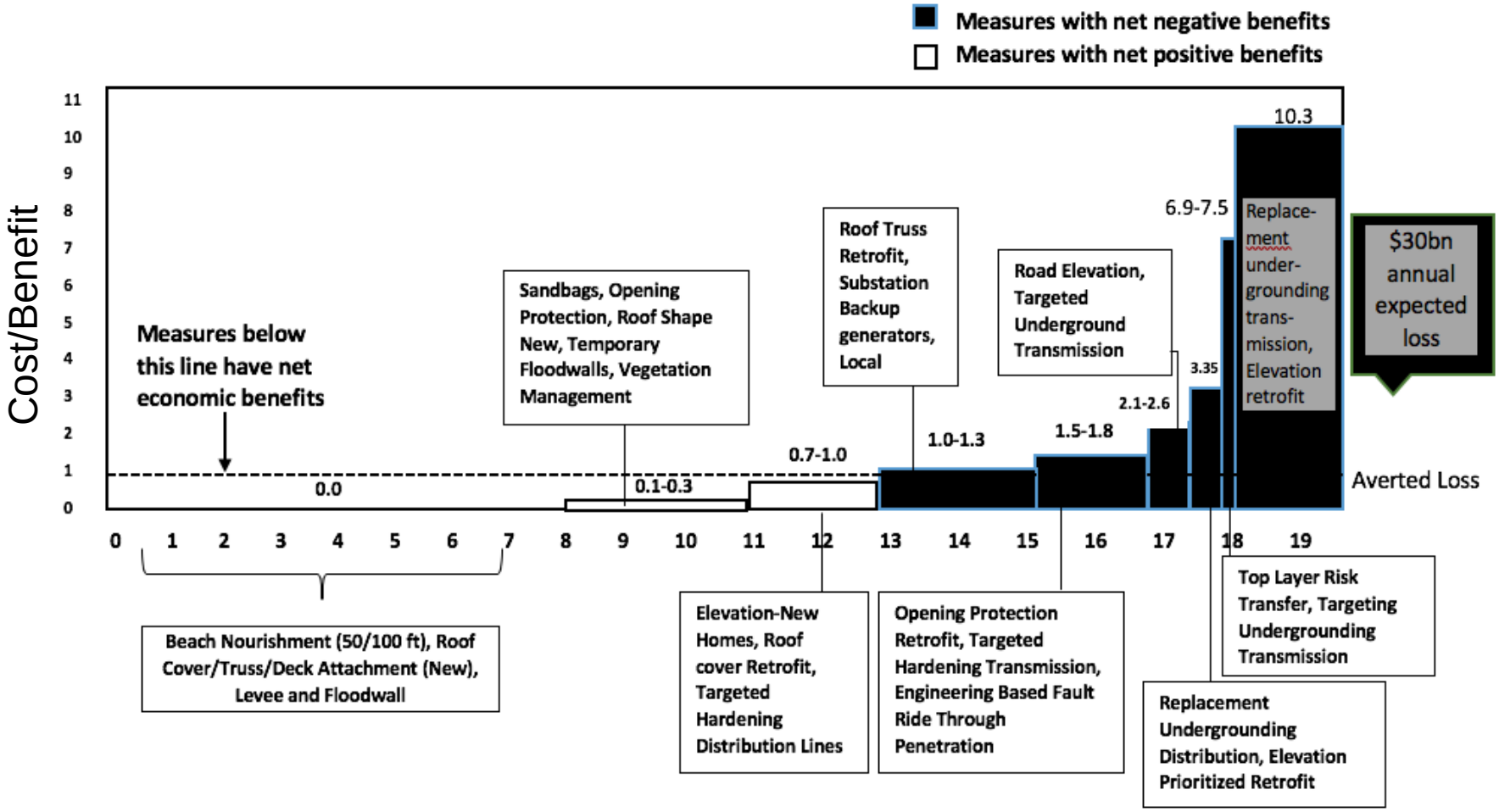
- lack of electricity,
- inaccessibility due to road damage, and
- supply-chain disruptions.

Adapting to the Impacts of Climate Change

Of the 50 states, Florida is the most vulnerable to rising sea levels, standing just a few feet above the current level. Miami is in an especially dangerous position because of its porous limestone foundation.

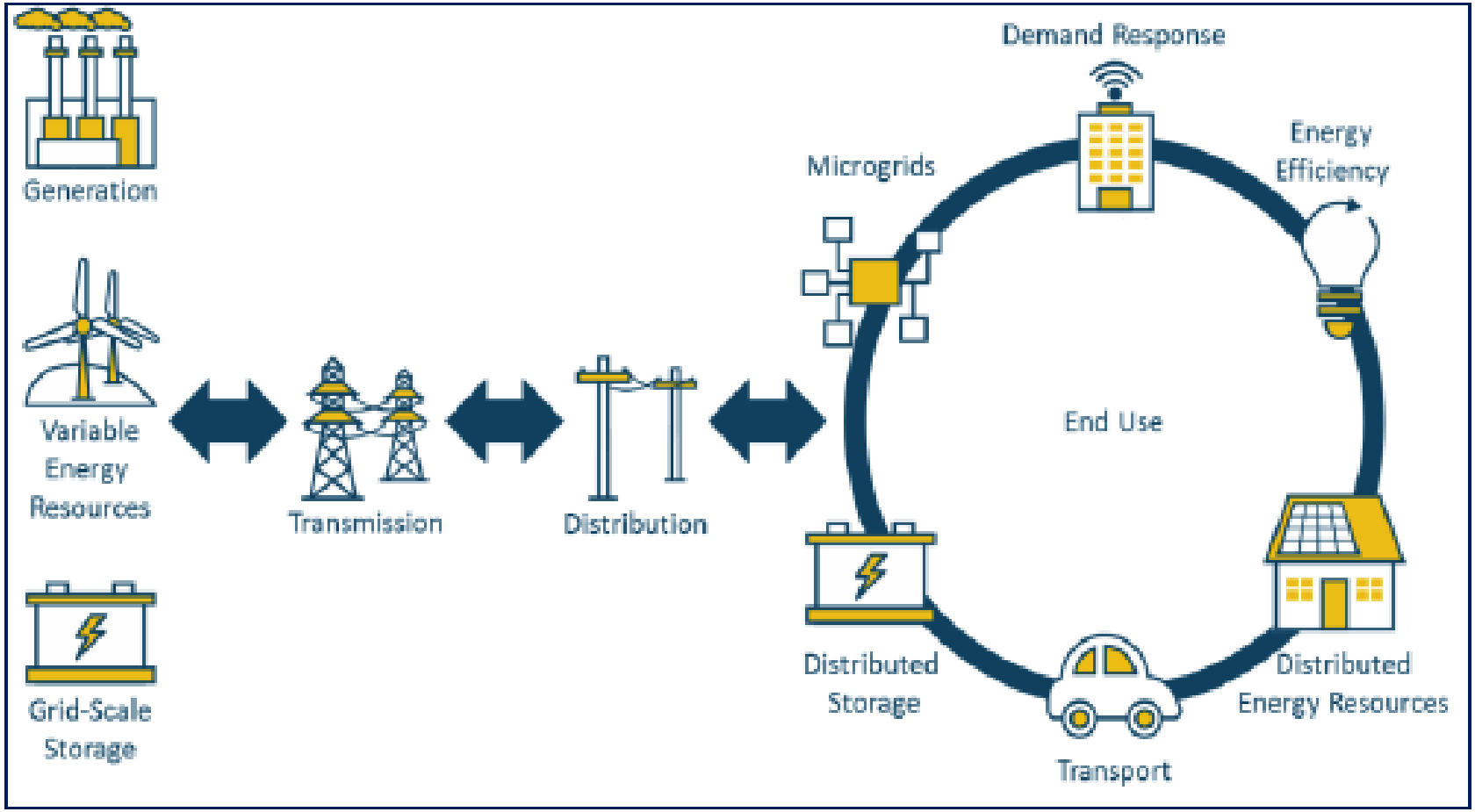
Source: http://www.nytimes.com/interactive/2014/03/27/world/climate-rising-seas.html?_r=1

Adaptation Options for Sea Level Rise in Florida



Source: Sovacool, Brown, and Valentine (2016) *Fact and Fiction in Global Energy Policy:* Johns Hopkins University Press; The Economics of Climate Adaptation Working Group. (2009). *Shaping Climate Resilient Development,* Figure 9.2.

The Shift to Distributed Energy Can Strengthen the Electric Grid



Source: DOE. 2017. *Quadrennial Energy Review: Transforming the Nation's Electricity System*, Figure S-3

Many Combined Heat and Power Systems Operated Thru Super-storm Sandy

- South Oaks Hospital – Amityville, NY, 1.25 MW reciprocating engine
- Greenwich Hospital – Greenwich, CT, 2.5 MW reciprocating engine
- Public Interest Data Center – New York, NY, 65 kW microturbine
- Co-op City – The Bronx, NY, 40 MW combined cycle
- Nassau Energy Corporation – NY, 57 MW combined cycle
- Bergen County Utilities Wastewater Plant – Little Ferry, NJ, 2.8 MW reciprocating engine
- New York University – New York, NY, 14.4 MW gas turbine
- Sikorsky Aircraft Corporation – Stratford, CT, 10.7 MW gas turbine

Source:
https://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_critical_facilities.pdf

The Shift to Distributed Resources is Happening

- Distributed solar capacity is now nearly 1% of total U.S. generating capacity (14 GW).
- >14 million electric customers are supplying power back into the grid.
- >16 million customers participate in wholesale or utility demand response or time-varying rate programs.
- >80 GW of combined heat and power now accounts for ~8% of total U.S. generating capacity.

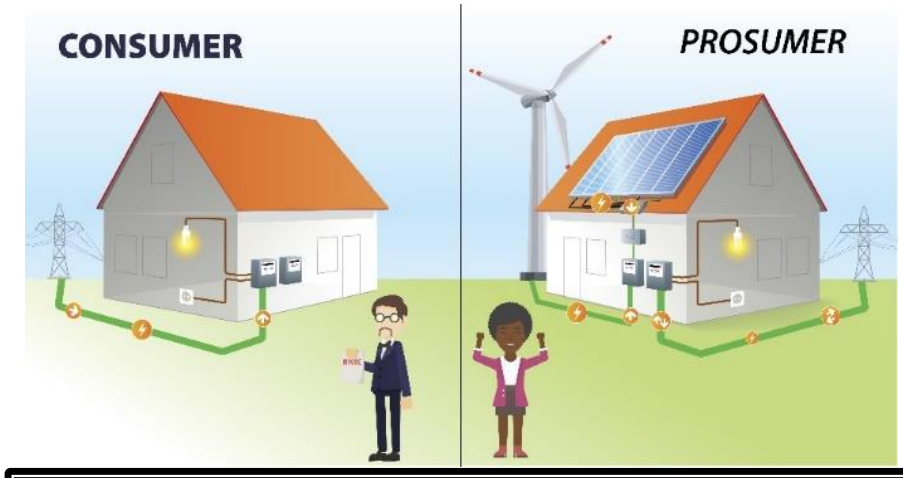
Emerging phenomenon:

- The charging cycles of 535,000 EVs are now being managed.

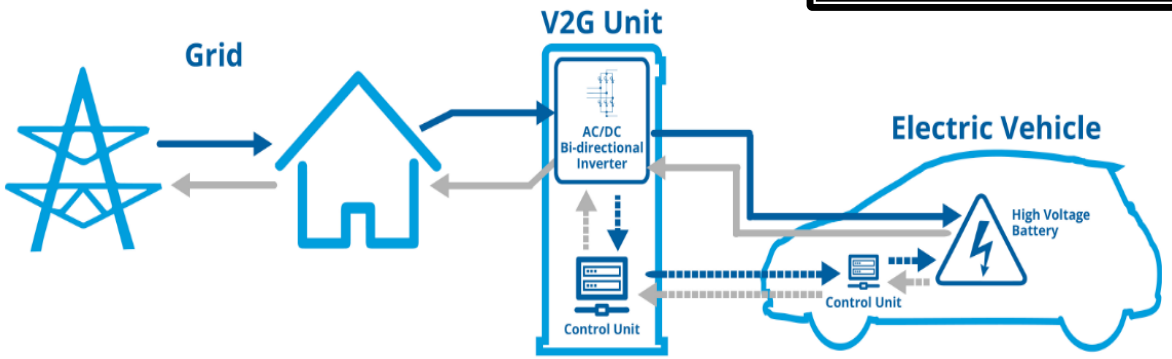
Source: DOE Electricity Advisory Committee, Smart Grid Subcommittee

“Prosumers” and the “Sharing Economy” are Emerging

- Consumers are becoming producers as well as consumers – “Prosumers”
  - Facilitated by the falling cost of solar panels
  - Home battery systems are on the move
  - Many more EV models available and a growing charging infrastructure



Grid-integrated vehicles could become another form of “prosumerism”



Open for smart business in your garage?

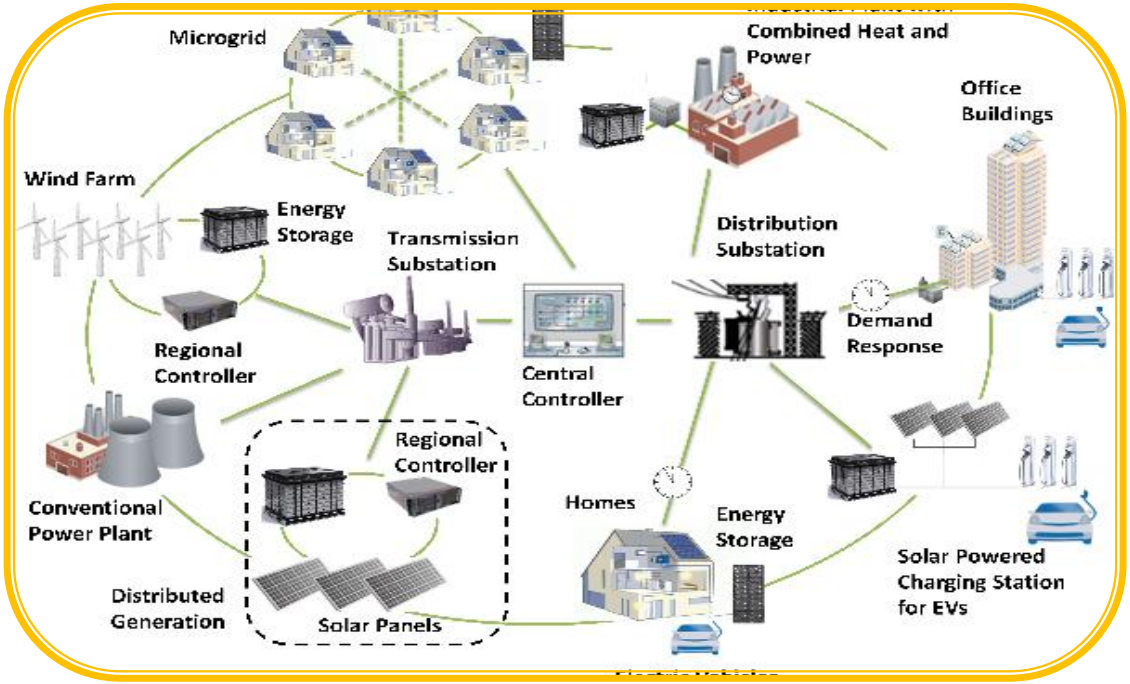
Distributed energy systems offer a climate-resilient development pathway

More renewable electricity + more electric vehicles = two complementary trends:

✓With renewables, EVs are even cleaner

✓With EVs, the grid can be more resilient

Business models + policy solutions are now needed.



Brown, Marilyn A., Shan Zhou, and Majid Ahmadi. 2018. "Governance of the Smart Grid: An international review of evolving policy issues and innovations," *Wiley Interdisciplinary Reviews (WIREs): Energy and Environment,* DOI: 10.1002/wene.290.

For More Information — and some late night reading??

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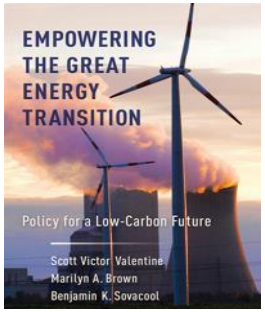
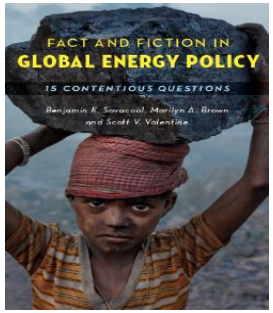
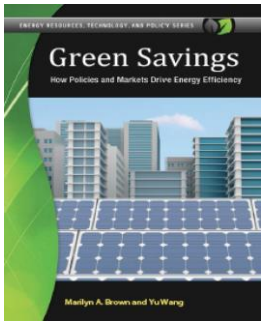


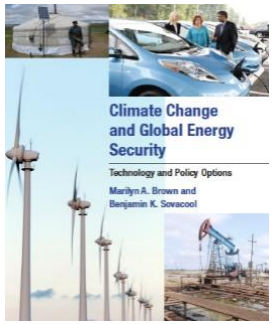
2019



2016



2015



2013